JEN-0052-D

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Jia et al.)
) Group Art Unit: 1754
Serial No.: 10/683,750)
)
Filed: October 10, 2003) Examiner: Paul A. Wartalowicz
)
For: DENTAL RESIN MATERIALS,)
METHOD OF MANUFACTURE)
AND USES THEREOF)

DECLARATION UNDER 37 CFR 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Weitao Jia, Ph.D., declares and says that:

1. I am an inventor of the above-referenced U.S. Patent Application No. 10/683,750, herein referred to as the "present application", which is a divisional application of and claims priority to, U.S. Patent Application No. 10/287,428, filed November 4, 2002, which claims the benefit of U.S. Provisional Application No. 60/336,883, filed November 2, 2001, U.S. Provisional Application No. 60/359,252, filed February 20, 2002, and U.S. Provisional Application No. 60/376,138, filed April 26, 2002.

2. I have reviewed and am familiar with the Office Action dated March 15, 2007. I have further read and am familiar with the references cited in the Office Action, in particular:

Japanese Patent Publication No. 360004561A (hereinafter "JP '561");

U.S. Patent No. 4,544,359 to Waknine (hereinafter "Waknine");

U.S. Patent No. 4,764,497 to Yuasa et al. (hereinafter "Yuasa");

U.S. Patent No. 6,387,981 to Zhang et al. (hereinafter "Zhang");
U.S. Patent No. 3,066,112 to Bowen (hereinafter "Bowen"); and
U.S. Patent No. 4,180,911 to Bullock (hereinafter "Bullock").

3. The independent claims in the present application claim nano-scaled silica particles in the form of chains. This type of silica is described in U.S. Patent No. 6,417,246, and can be purchased, for example from Nissan Chemical Industries, Ltd, under the trade name of SNOWTEX®-PS and SNOWTEX®-UP silica sol. Figures 1 and 2 are transmission electron microscope (TEM) images of silica in the form of chains. In particular, Figure 1 is a TEM image of SNOWTEX®-PM silica sol, and Figure 2 is a TEM image of SNOWTEX®-UP silica sol as shown in a brochure from Nissan Chemical Industries, Ltd.

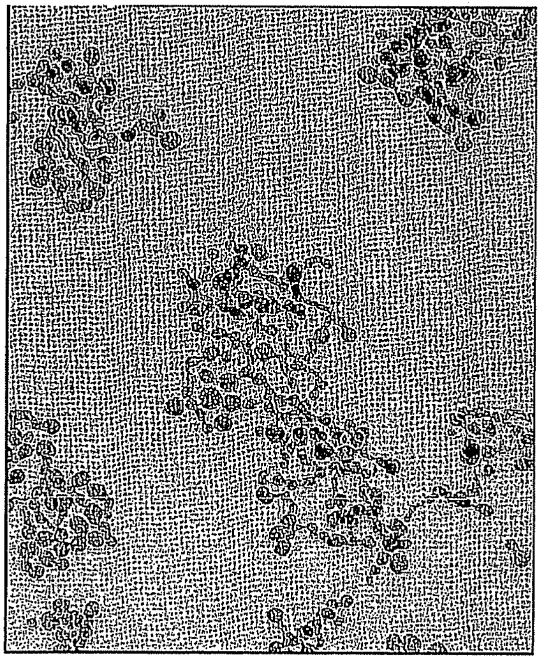


Figure 1

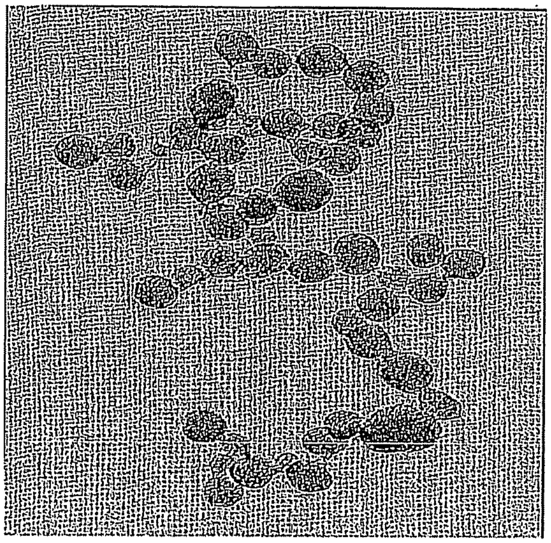


Figure 2

4. As described in the attached "SNOWTEX®" download from Nissan Chemical at page 6, SNOWTEX®-PS silica sol is in the form of a "string of pearl particles". It is known in the art that the structure and secondary morphology of the silica particles in a silica sol depend on conditions used to form the sol, for example the solvent, the starting materials, the other components in the sol, and other processing conditions such as time, pH, and temperature. One of ordinary skill in the art would therefore know that string of pearls form of the SNOWTEX®-PS silica sol is not necessarily found in all sol gels. Indeed, it appears to be generally recognized the structure is unique. See, for example, the attached Abstract by T.C. Chao et al., describing a "unique pearl necklace-shaped colloidal silica" that has "become commercially available." See also, the attached download from "Pulp and Paper Online," which states that "The SNOWTEX®-PS series is structured like a chain of pearls . . . this is in contrast to conventional silica sols, which are monodispersed spherical particles."

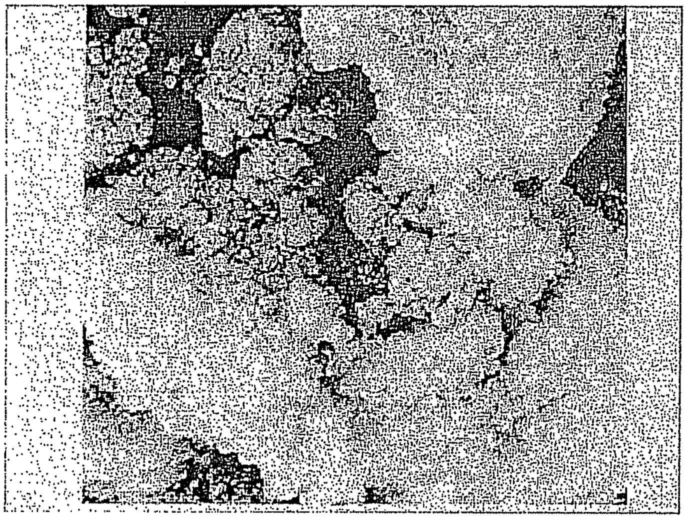
Further, it is known in the art that the structure and secondary morphology of the silica particles isolated from a silica sol depend on the conditions used to form the sol, for example the solvent, the starting materials, the other components in the sol, and other processing conditions such as time, pH, and temperature. For example, the attached article by S. Tabatabei et al. discloses that:

> Depending on the synthesis process parameters, the structure of colloidal particles may vary from isolated spherical particles to agglomerates of complex structures[5]. Therefore, a major concern associated with obtaining colloidal silica particles is the control of structural features, such as average diameter amd morphology of the particles.

The article further concludes that the morphology and structure of silica nanoparticles formed therein using a sol-gel method from TEOS in ethanol depends on the molar ratio of reagents. One of ordinary skill in the art would therefore know that chain structure of the silica derived from a sol such as the SNOWTEX®-PS silica sol is not necessarily found in all silicas derived from a sol gel.

5. Figure 3 depicts a TEM image of colloidal fumed silica, and shows that in contrast to the chains of Figures 1 and 2, the colloidal fumed silica has an irregular shape, usually with porosities within due the heat precipitation step used in processing.

Figure 3



6. Fused silica as described in Bowen is produced using a high temperature fusion process. For example, it can be produced using high purity silica sand as the feedstock, and is normally melted using an electric furnace. Synthetic fused silica is made from a silicon-rich chemical precursor usually using a continuous flame hydrolysis process which involves chemical gasification of silicon, oxidation of this gas to silicon dioxide, and thermal fusion of the resulting dust (although there are alternative processes). This results in a transparent glass with an ultra-high purity and improved optical transmission in the deep ultraviolet. As described in Bowen, the fused silica is then ground to the desired particle size, including nanometer size. Such silica particles do not form chains as shown in Figures 1 and 2. The silica is further amorphous, not crystalline, as shown at page 992 of Hawley's Condensed Chemical Dictionary, attached hereto.

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the patent.

Date: 8/20/07

Weitao Jia

Nissan Chemical
America Corporation

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SNOWTEX®

SNOWTEX® is colloidal silica with many applications for paper, fibers, steel and catalysts. Most recently, it has been used by the semiconductor industry as a polishing agent for silicon wafers. Without the development of chemicals such as SNOWTEX, the electronics industry would not be where it is today.

Only Nissan Chemical produces proprietary particle shapes such as SNOWTEX-UP and SNOWTEX-PS.

SNOWTEX comes in a variety of types to suit your needs.

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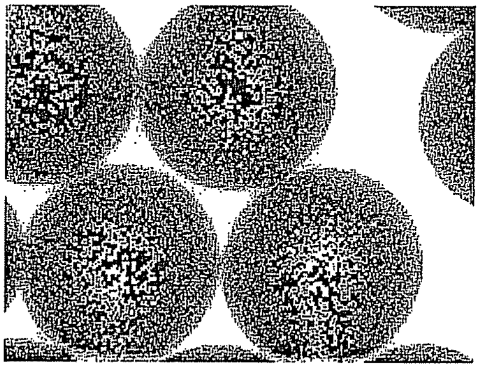
More.

Applications of SNOWTEX

SNOWTEX has a wide variety of industrial applications such as:

- Frictionizing
- Adhesion and coating
- Binding and hardening
- Polishing
- Investment casting
- Impregnation filler
- Battery manufacturing
- Modification and strengthening of organic resins



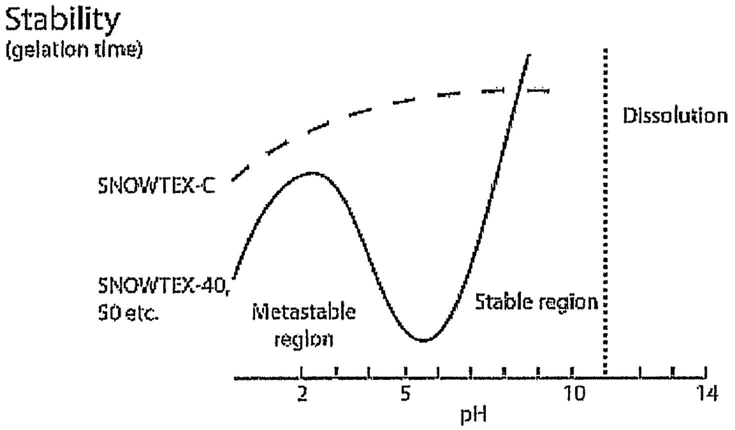
Particles and Surface State

SNOWTEX® is colloidal silica made by growing mono-dispersed, negatively charged, amorphous silica particles in water. OH ions exist at the surface of the p
electric double layer formed by alkali ions. Stabilization is achieved by the repulsion between the same negat
particles. Disturbance of the charge balance will cause the colloidal silica to aggregate, resulting in high visco
solution.

Stability

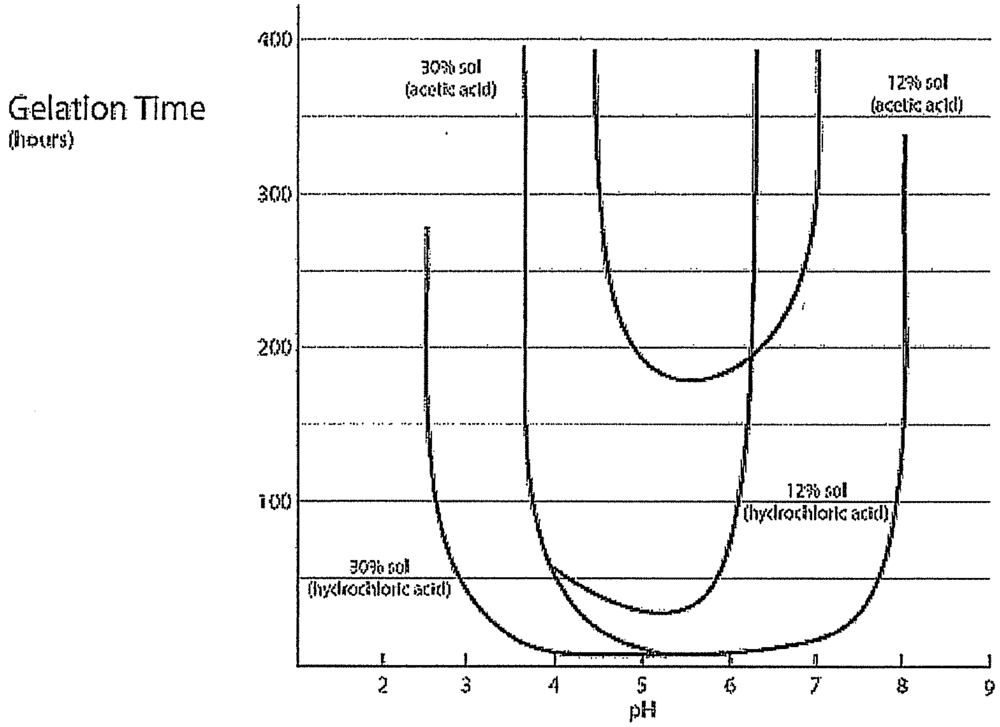
Effects of pH change

The higher the concentration or the smaller the particle size, the greater the effect pH change will have on ge
stability. SNOWTEX is very stable in the 2-4 and 8-10 pH ranges as illustrated in the diagram below. If a form
system has a neutral pH, or the formulation requires a colloidal silica with greater stability, SNOWTEX-C can l



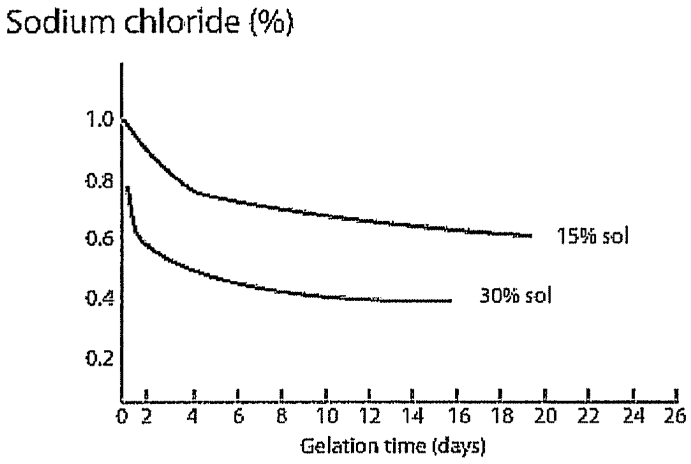
When the pH exceeds 10.5 with a strong alkali, such as caustic soda or sodium silicate, coagulation and disso particles occurs.

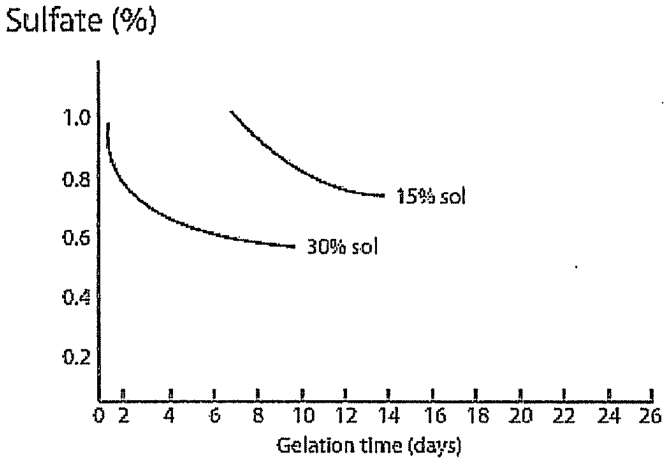
Long chain amines tend to cause SNOWTEX to gel, but ethylamine, morpholine and other similar amines tend SNOWTEX maintains its stability for a fairly long time even when the pH of an alkaline SNOWTEX grade is low of an acid. However, the gelation time differs with the kind of acids used for pH adjustment. The gelation tim changed by adding hydrochloric acid and acetic acid is shown below. Organic acids tend to provide better stal gelation time, depending on the SiO_2 concentration and particle size.



Effects of salts and electrolytes

Polyvalent metal ions will cause SNOWTEX to gelate. This is because the polyvalent ions interfer with the surf
SNOWTEX. The resulting charge imbalance causes the particles to agglomerate. The surface charge maintain
stability. The degree of gelation is not uniform, and varies depending on the type, concentration, temperatur
electrolyte used. Monovalent salts react slowly, but polyvalent salts such as alum, react quickly at pH 9 and
lowered, the effect of alum and magnesium sulfate decreases. This electrolytic effect on SNOWTEX is useful t
down the gelation. The gelation time of SNOWTEX at 52° C with addition of sodium chloride and sulfate are d


Sodium chloride (%)


Sulfate (%)

Compatibility with organic solvents

Alcohol, acetone and other polarized solvents can be mixed with SNOWTEX. However, there is a mixing limit occur. The compatibility with alcohol when the pH is changed is shown below as an example. SNOWTEX-O ca alcohol at any proportion.

When alcohol is mixed with SNOWTEX-20 the stability is very good. *

	SNOWTEX-20	METHANOL	ETHANOL	Stability
	grams	grams	grams	(85°C)
No.1	90	10	-	24 hours or more
No.2	80	20	-	24 hours or more
No.3	90	-	10	24 hours or more
No.4	80	-	20	Gelled in 13 hours

*This will dilute SNOWTEX-20. SNOWTEX-20 contains 20% SiO_2 by weight.

Lowering the pH of the SNOWTEX-20 with hydrochloric acid to 3.9 and then mixing the alcohol significantly reduces t

	SNOWTEX-20	METHANOL	ETHANOL	Stability
	grams	grams	grams	(85°C)
No.5	90	10	-	1 hour 10 minut
No.6	80	20	-	1 hour 45 minut
No.7	90	-	10	1 hour 28 minut
No.8	80	-	20	1 hour 50 minut

Compatibility with surfactants

Generally, SNOWTEX is compatible with anionic and nonionic surfactants. Compatibility is dependent on impu composition of the surfactant. Incompatibility may cause the SNOWTEX to gel or agglomerate. Therefore, it is the surfactant carefully. SNOWTEX-C is compatible with a wide range of surfactants.

Compatibility with emulsion resins and water soluble resins

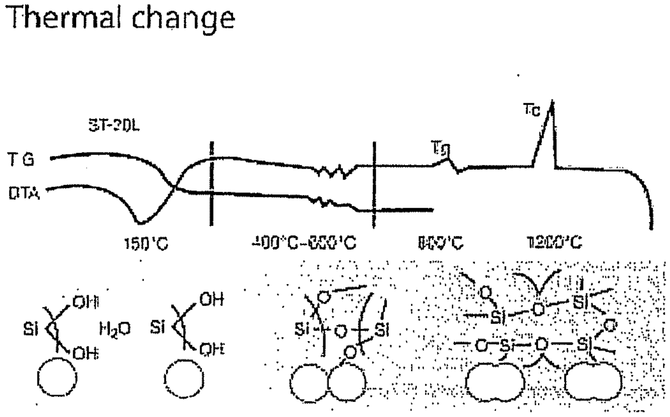
SNOWTEX is compatible with emulsion resins and water soluble resins having the same pH and electric charg emulsion resin, gelation and separation may occur depending on which emulsifier is used. Therefore, it is imp emulsifier carefully. SNOWTEX-C is also compatible with a wide range of emulsifiers.

Dry Gel

When SNOWTEX is dried, a dry gel is formed. Slowing the drying time will produce smaller agglomerates as v particle-size distribution. This results in a harder dry gel solid.

Thermal change

The illustration below compares the differential thermal analysis (DTA) and the thermal gravimetric analysis c The transition of the silica particles is highlighted in the illustration below.


Thermal change

At approximately 150°C, water desorbs from the silica gel, resulting in a weight reduction of approximately 5 silanol groups at 400-700°C causes another small weight reduction. Up to this temperature, the particles rem approximately 800°C, surface fusion between the silica particles occurs. At the glass transition (Tg), the mecl silica increases. At approximately 1200°C , an exothermic peak is caused by crystallization (Tc) into cristoball is estimated at 1700°C. The glass transition temperature, crystallization temperature and melting point depe sodium ion in the SNOWTEX. The melting points of SNOWTEX-O and SNOWTEX-N are higher because they co ions.

SNOWTEX ®	ST-20L	ST-40	ST-50	ST-C	ST-N	ST-O
SiO2 (wt%)	20-21	40-41	47-49	20-21	20-21	20-21
Na2O (wt%)	< 0.3 *2	< 0.6	< 0.6	< 0.2	< 0.04 *1	< 0.04 *2
pH	9.5-11.0	9.0-10.5	8.5-9.5	8.5-9.0	9.0-10.0	2-4
Particle Shape	Spherical	Spherical	Spherical	Spherical	Spherical	Spherical
Particle Size (nm)	40-50	10-20	20-30	10-20	10-20	10-20
Viscosity (mPa.s. at 25° C)	< 3	< 25	< 50	< 10	< 6	< 3
Specific Gravity (25°C)	1.12-1.14	1.28-1.35	1.36-1.40	1.12-1.14	1.12-1.14	1.12-1.14
Appearance	Opalescent	Clear to opalescent	Clear to opalescent	Clear to opalescent	Clear to opalescent	Clear to opalescent

*1: Flammable alkali (as Na_2O) is less than 0.04 wt%. And NH_3 is less than 0.2 wt%.
*2: Flammable alkali (as Na_2O) is less than 0.03 wt%.

Note: These are *typical* properties of SNOWTEX.

Properties of SNOWTEX-PS

The unique string-of-pearl particles and high viscosity of SNOWTEX-PS give it excellent bonding and coating conjunction with its high fluidity, make SNOWTEX-PS excellent for:

- Coating paper, plastics and metals
- Binder for catalyst
- Modification of paints and coating agents
- Fiber treatment
- Binding agent
- Casting

SNOWTEX ®	ST-PS-M	ST-PS-MO	ST-PS-S	ST-PS-SO
SiO2 (wt%)	20-21	18-19	15-16	15-16
Na2O (wt%)	< 0.2	< 0.03	< 0.20	< 0.02
pH	9.0-10.5	2-4	9.0 - 10.5	2-4
Particle Shape	String-of-pearls	String-of-pearls	String-of-pearls	String-of-pearls
Particle Size (nm) / Dynamic light scattering method	18-25/80-150	18-25/80-150	10-15/80-120	10-15/80-120
Viscosity (mPa.s. at 25°C)	< 100	< 100	< 100	< 100
Specific Gravity (25°C)	1.12-1.14	1.10-1.12	1.08 - 1.11	1.08 - 1.11
Appearance	Milky white	Milky white	Milky white	Milky white

String-of-pearl particles have a diameter of 18-25 nm with a length of 80-100 nm.

Note: These are *typical* properties of SNOWTEX.

Properties of SNOWTEX-UP

The colloidal particle of SNOWTEX-UP has a unique, elongated shape unlike typical, spherical silicasol. SNOW advantages.

The elongated particle shape and high viscosity of SNOWTEX-UP give it excellent properties for film forming, migration.
This can be useful for:

- Coating paper, plastics and metals
- Binder for refractories
- Binder for ceramics, glass and fiber
- Textile treatment

SNOWTEX ®	ST-OUP	ST-UP

SiO2 (wt%)	15-16	20-21
Na2O (wt%)	< 0.03	< 0.35
pH	2-4	9.0-10.5
Particle Shape	Elongated	Elongated
Particle Size (nm)	9-15/40-100	9-15/40-100
Viscosity (mPa.s. at 25°C)	< 20	< 100
Specific Gravity (25°C)	1.08-1.11	1.12-1.14
Appearance	Opalescent	Opalescent
Elongated particles have a diameter of 9-15 nm with a length of 40-100 nm. Ammonia-stabilized ST-UP is available upon request.		

Note: These are *typical* properties of SNOWTEX.

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Experimental study of the synthesis and characterisation of silica nanoparticles via the sol-gel method

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Abstract. Silica nano-particles were synthesised by chemical methods from tetraethylorthosilicate (TEOS), ethanol (C_2H_5OH) and deionized water in the presence of ammonia as catalyst at room temperature. The morphology and structure of colloidal silica particles formed depend on the molar ratio of reagents. The formation of silica particles has been investigated using different solvents: ethanol and ethanol-glycerol. The nature and morphology of particles was investigated by scanning electron microscopy (SEM), transmission electron microscopy (TEM), transmission electron microscopy (TEM) and X-ray diffraction (XRD).

1. Introduction

Interest in the sol-gel processing of inorganic ceramic and glass materials began as early as the mid-1800s with Ebelman [1], and Graham's [1] studies on silica gels. The sol–gel technique is the most common method of synthesising silica nano-particles. It involves the simultaneous hydrolysis and condensation reaction of the metal alkoxide [1]. However, the physical properties of nanosized spherical colloidal silica, prepared from tetraethylorthosilicate (TEOS) in ethanol, are difficult to reproduce in that they often depend on the method of isolation of the product. Kolbe [2] in 1956 observed formation of silica particles by reacting TEOS in alkali solution with water in the presence of certain bases.

In 1968 Stöber and Fink developed a system of chemical reactions which controlled the growth of spherical silica particles. The importance and advantages of mono-dispersed nanometre-sized particles were shown not only scientifically, but also in various industrial applications, e.g. as catalysts, pigments or pharmaceuticals [3]. Of these particles, SiO_2 nano-particles are used to make electronic substrates, thin film substrates, electrical insulators, thermal insulators and humidity sensors. The silica particles play a different role in each of these products. The quality of some of these products is highly dependent on the size and size distribution of the silica particles. Commercial silica has a broad size distribution and varying levels of metal contaminants. It is imperative to have silica particles of a narrow size distribution and a high purity [4]. Depending on the synthesis process parameters, the structure of colloidal particles may vary from isolated spherical particles to agglomerates of complex

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structures [5]. Therefore, a major concern associated with obtaining colloidal silica particles is the control of structural features, such as average diameter and morphology of particles. Silica particles are suitable candidates for application in chemo-mechanical polishing (CMP) because silica can be directly precipitated as monodispersed spheres, their narrow size distribution being an important requirement. The synthesis of a wide range of mono-dispersed silica particles with various mean particle sizes will be helpful for modern polishing manufacturers in producing a series of polish grades optimized to a particular application.

The purpose of the present study is to investigate different solvents and their effects in preparing mono-dispersed silica particles. Different solvents such as ethanol, ethanol-glycerol were considered.

2. Experimental

TEOS, NH_4OH aqueous solution and ethanol (EtOH) were used (Merck Co.) and the water used for the sample preparation was purified by both ion-exchange and distillation. Reagents were mixed into the two starting time solutions of ethanol: (I) TEOS/ EtOH; and (II) NH_4OH/ H_2O/ EtOH. The contents of the solutions (I) and (II) were adjusted so that the concentrations of TEOS, H_2O, and NH_4OH would be at the prescribed concentrations. The solutions were prepared in a glove box at room temperature under dry air. The humidity in the glove box was kept below a few percent [5]. The solutions (I) and (II) were mixed with each other at 298 K, and the mixture was stirred vigorously by hand for approximately 6s. The glycerol was added directly to the water/ammonia/ethanol mixture prior to the addition of TEOS.

Depending on different molar ratio of reagents, the condensation reaction began after various times. This could be easily observed, because, after the invisible hydrolysis reaction forming silicic acid, the condensation of the supersaturated silicic acid was indicated by an increasing opalescence of the mixture starting 2-10 minutes after adding the TEOS. After this transformation, a turbid white suspension formed after a few minutes more. Samples for SEM and TEM observation were prepared by diluting the sample liquid with ethanol and dispersing with ultrasound.

3. Results & Discussion

Colloidal silica nano-particles are based on the hydrolysis reaction of silicon alkoxide where the resulting particle size and morphology depend strongly on the hydrolysis kinetics. In the selected constituent concentrations, spherical, silica particles can be obtained. The reaction time of this synthesis required 15 minutes. The reaction continues until the solution is super-saturated [4]. To investigate the possibility of tailoring the particle size and maybe the particle size distribution, a kinetic study of the particle size evolution as a function of reaction time was carried out. X-ray diffraction using CuKα radiation (Philips X'pert) was used to determine the crystalline structure of silica particles [7]. The silica particles were amorphous according to XRD with peaks less than $2\theta=10°$ conforming to the JCPDS file (79-1711). This demonstrates that a high percentage of these particles are amorphous, but a few of them are crystalline, as the energy of amorphous silica is very close to that of crystalline silica [2]. Vacassy and Flatt [4] reported that when one is interested in fine particles, the water concentrations should be fixed at 0.2 - 3.2 M, also the molar ratio of ammonia and TEOS should be the same. Silica nano-particles were prepared taking into account these considerations. Fig. 2 shows these particles and also the narrow size distribution of these particles.

The final product was analysed by XRF. The result of this analysis is shown in Table 1.

Table 1: The result of XRF analysis.

	LOI	SiO_2	Cl	Zn	Br
wt %	18.096	81.854	0.04	0.01	0.015

In this table, LOI (Loss on Ignition) could consist of water, CO_2, sulfur etc. Pure reagents (99.9+% pure Merck) were used for synthesizing this particles. Table 1 shows that the purity of silica nano-particles is high, but some impurities could arise from the experimental fabrication process.

Vasconcelos and Campos [8] have considered the effect of different molar ratios of reagents on the structure and morphology of silica particles at room temperature. When the reaction was conducted at 60° C, silica nano-particles were also obtained. This temperature was based upon a limitation of the boiling point of the reagents.

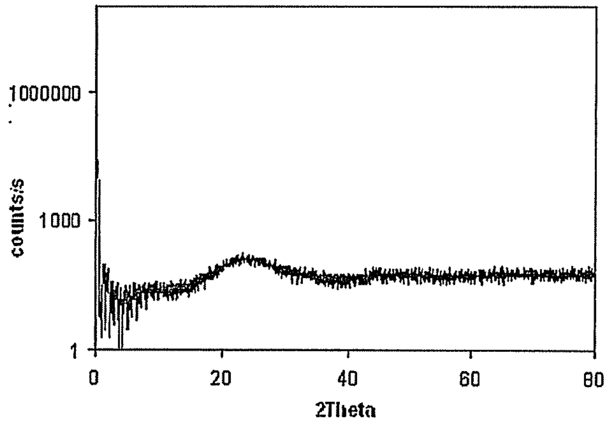


Fig. 1: X-ray spectra of colloidal silica particles.

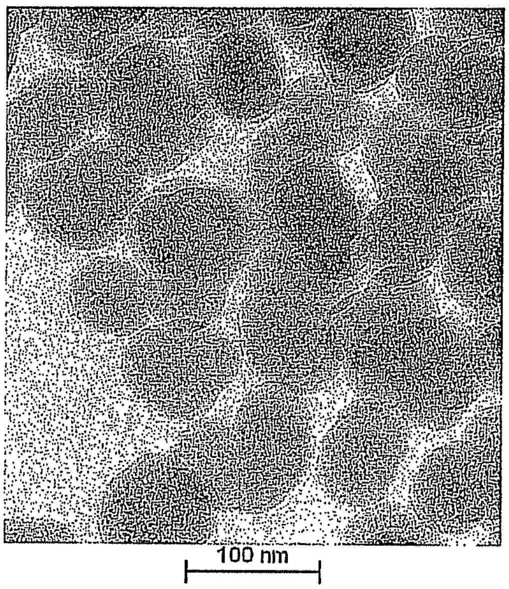
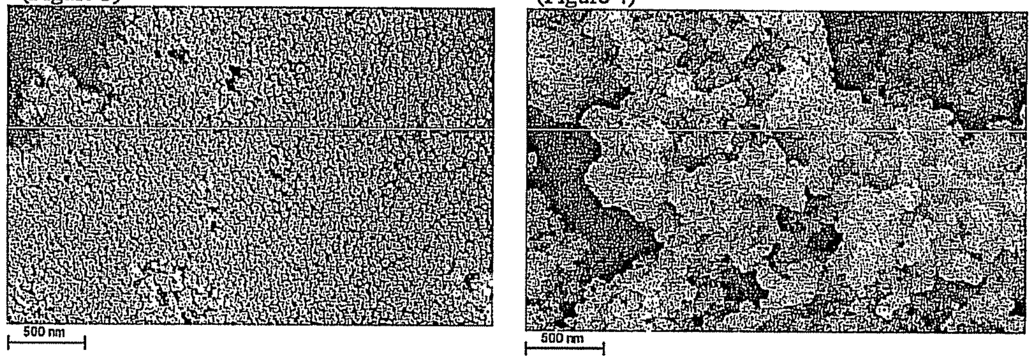


Fig. 2: TEM image of silica particles (TEOS : water : ammonia molar ratio = 0.2 : 1 : 0.2).


(Figure 3)

(Figure 4)

Figs. 3,4: SEM micrographs of silica particles obtained from a molar ratio of Water : TEOS : Ammonia : Ethanol = (Fig. 3) 1 : 4 : 6 :6; (Fig. 4) 1 : 4 : 6 : 24, respectively.

Figures 3 and 4 show spherical and agglomerated silica nano-particles, which were obtained using different molar ratios of reagents; the molar ratio of the solvent is also important. With a lower molar ratio of solvent (ethanol), agglomerated silica particles were obtained. Park and Kim [6] have shown when a narrow size distortion is required, a small molar ratio of ethanol should be employed. The optimum conditions for synthesizing silica nano-particles were considered to be with the same molar ratio of TEOS and ammonia and a higher molar ratio of ethanol giving rise to smaller silica nano-particles with a broad distribution of particle sizes [5].

Stober and Fink [3] have shown the different solvent effects on the size of particles [3]. Using different solvents such as methanol, ethanol, propanol, butanol and ethanol-glycerol, different structures were obtained. From methanol and ethanol-glycerol, a stable sol could be obtained, but when butanol and ethanol were used, precipitation could be easily observed. Different experiments show that the presence of glycerol during synthesis affects the precipitation.

4. Conclusion

Spherical silica particles with a very narrow particle size distribution have been synthesised by the hydrolysis reaction of TEOS in ethanol containing water and ammonia. The morphology and the average diameter of colloidal silica particles depend on the proportion of the reactants. Silica nanoparticles were obtained via the same molar ratio of TEOS, ammonia and also a high molar ratio of ethanol. Different solvents have different effect on the size of the silica particles. Using methanol and ethanol-glycerol, a stable sol could easily be obtained.

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Silylation of Partially Aggregated Colloidal Silica Nanoparticles for Reinforcement in Silicone Elastomers

Author(s):
Timothy C. Chao and Debora F. Bergstrom

Aqueous suspensions of colloidal silicas are readily silylated with chlorosilanes in the presence of acid and isopropyl alcohol without aggregation of the silica particles. By using chlorosilanes, spherical nanoparticles with controlled functionality can be made and transferred to an organic phase to provide stable, water free suspensions. The hydrophobic colloidal silica particles readily disperse into silicone polymers. In order to provide mechanical reinforcement comparable to traditional fumed silicas, a high filler loading of ca. 60 wt % mono-dispersed colloidal silicas need to be used. Recently a unique pearl necklaced-shaped colloidal silicas become commercially available. These nanoparticles are successfully silylated and they maintain the original structures as evidenced by transmission electron microscopy (TEM). They are compounded into silicone polymers at ca. 30 wt % and they provide excellent viscosities and mechanical properties, especially the tear strengths. In this paper, we present the silylation, characterization and mechanical properties of these partially aggregated colloidal silica nanoparticles in silicone elastomers.

Member Price: $0; **Non-Member Price:** $20.00
Track ID:
Paper #: U5.11
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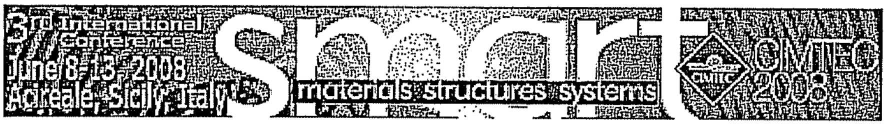

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The Snowtex-PS series has a very unique particle shape. The unique shape results in exceptional film forming ability and a highly porous gel. Snowtex-PS is structured like a chain of pearls. The individual particles are 10 – 50 nm in diameter, chemically bonded to a length of 50 – 400 nm. This is in contrast to conventional silica sols, which are monodispersed spherical particles. The Snowtex-PS will increase hardness and abrasion resistance of paint and coatings.

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terial for high-temperature mortars.
See "Aerosil"; "Cab-O-Sil."

silica, fused. (amorphous quartz).
CAS: 60676-86-0. O_2Si.
Properties: Mw 60.09. Made up of spherical submicroscopic particles under 0.1 micron in size.
Hazard: TLV: 0.1 mg/m³ (Respirable Fraction).
Use: Concrete, grouts, mortars, elastomers, refractory and coating applications.
See silica; quartz, fused.

silica gel.
CAS: 7631-86-9. (silica, amorphous hydrated; silicic acid). A regenerative adsorbent consisting of amorphous silica. Noncombustible.
Derivation: From sodium silicate and sulfuric acid.
Grade: Commercial grades capable of withstanding temperatures up to 260–315C are supplied in the following mesh sizes: 3–8, 6–16, 14–20, 14–42, 28–200, and through 325.
Hazard: TLV: TWA (nuisance particulate) 10 mg/m³ of total dust (when toxic impurities are not present, e.g., quartz <1%).
Use: Dehumidifying and dehydrating agent, air-conditioning, drying of compressed air and other gases and liquids such as refrigerants and oils containing water in suspension, recovery of natural gasoline from natural gas, bleaching of petroleum oils, catalyst and catalyst carrier, chromatography, anticaking agent in cosmetics and pharmaceuticals, in waxes to prevent slipping, in dietary supplements.
See silicic acid; "Britesorb" *[PQ]*.

"Silic AR" *[Mallinckrodt]*. TM for silica-gel-based formulations suitable for various chromatographic applications. The numerical suffixes indicate the approximate pH of a 10% slurry. Letters F, G, or GF indicate that the product contains a fluorescent material, gypsum binder, or both. "TLC" indicates suitability for thin-layer chromatography.

silicate. Any of the widely occurring compounds containing silicon, oxygen, and one or more metals with or without hydrogen. The silicon and oxygen may combine with organic groups to form silicate esters. Most rocks (except limestone and dolomite) and many mineral compounds are silicates. Typical natural silicates are gemstones (except diamond), beryl, asbestos, talc, clays, feldspar, mica, etc. Portland cement contains a high percentage of calcium silicates. Best known of the synthetic (soluble) silicates is sodium silicate (water glass).
Hazard: (Natural silicate dusts) Toxic by inhalation.
Use: Fillers in plastics and rubber, paper coatings, antacids, anticaking agents, cements.

silicate garden. The irregular, colored, tubular growths formed in dilute aqueous silicate solutions by dropping water solutions of heavy metal salts into it.

silicic acid. (hydrated silica).
CAS: 7699-41-4. $SiO_2 \bullet nH_2O$. The jellylike precipitate obtained when sodium silicate solution is acidified. The proportion of water varies with the conditions of preparation and decreases gradually during drying and ignition, until relatively pure silica remains. During drying the jelly is converted to a white, amorphous powder or lumps.
Use: Laboratory reagent and reinforcing agent in rubber.
See silica gel.

silicochloroform. See trichlorosilane.

silicol. Silicic oxide casein metaphosphate.

silicomanganese. Alloys consisting principally of manganese, silicon, and carbon.
Use: Low-carbon steel in which silicon is not objectionable. Silicon manganese steels are used for springs and high-strength structural steels.
See ferromanganese.

silicomolybdic acid. See 12-molybdosilicic acid.

silicon. (silicon powder, amorphous).
CAS: 7440-21-3. Si. Nonmetallic element Atomic number 14, group IVA of the periodic table, aw 28.086, valence = 4, three stable isotopes. It is the second most abundant element (25% of the earth's crust) and is the most important semiconducting element; it can form more compounds than any other element except carbon.
Properties: Dark-colored crystals (the octahedral form in which the atoms have the diamond arrangement). The amorphous form is a dark-brown powder (see silicon, amorphous). D 2.33, mp 1410C, bp 2355C, Mohs hardness 7, dielectric constant 12, coordination number 6. Soluble in a mixture of nitric and hydrofluoric acids and in alkalies; insoluble in water, nitric acid, and hydrochloric acid. Combines with oxygen to form tetrahedral molecules in which one silicon atom is surrounded by four oxygen atoms. In this respect it is similar to carbon. It is also capable of forming –Si=Si– double bonds in organosilicon compounds.
Occurrence: Does not occur free in nature but is a major portion of silica and silicates (rocks, quartz, sand, clays, etc.).
Derivation: Crystalline silicon is made commercially (96–98% pure) in an electric furnace by heating SiO_2 with carbon, followed by zone refining. It can be purified to 99.7% by leaching. The ultrapure semiconductor grade (99.97%) is obtained by reduction of purified silicon tetrachloride or trichlorosilane with purified hydrogen; the silicon is deposited on hot filaments (800C) of tantalum or tungsten. In a one-step method, sodium fluorosilicate is reacted with sodium, the heat produced being sufficient to form silicon tetrafluoride; this, when reacted with sodium, yields high-purity silicon and sodium fluo-